ACCIAI PER OLEODOTTI (PIPELINE)

The first "pipelines" were laid in China about 1000 B.C., while the first oil pipeline was built in Baku, 1878, it was above 10 km long and 2" in diameter and it was realized to decrease the cost of transportation by above 90%.

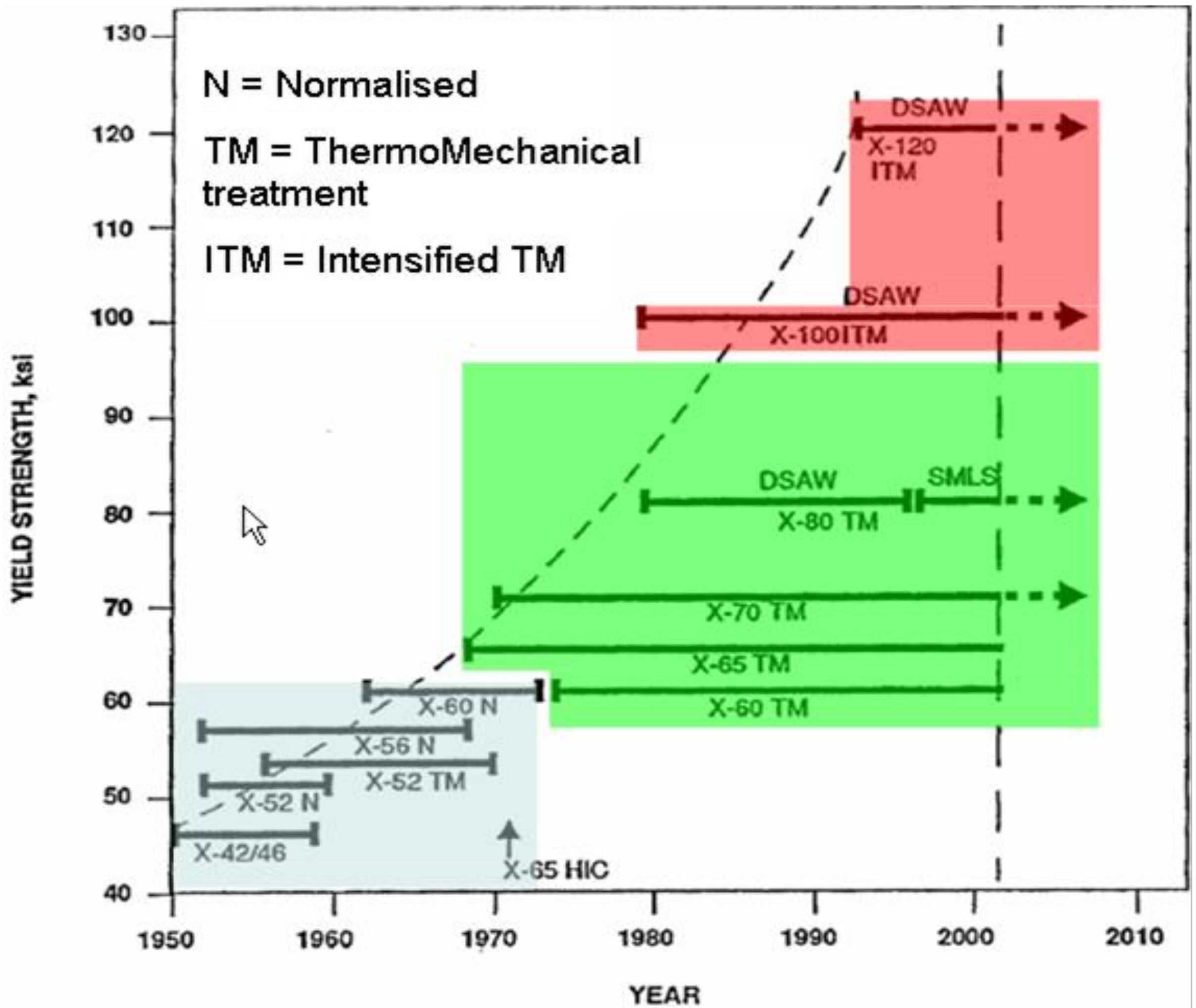
In the late '20s, the manufacturers started to weld pipe with electric resistance-welded that brought a "tremendous upgrade" compared to acetylene weld.

The development of a national pressure piping code in USA started in 1915. Later in 1935 the American Tentative Standard Code for pressure piping, B31, was issued. The control of the external corrosion had in the late '40s a real key stone as many pipeline operators introduced the cathodic protection for new pipelines.

Some milestones in "in the trench" construction started in the same period with the large spread of radiography

However, the real big leap in pipeline steel quality started in the '60s, as the use of low carbon steels resulted in tougher grades. In that time other improvement in pipeline industry procedures, as testing all new pipeline construction by a hydrostatic pressure "field" test, assured the proper serviceability of the pipe before its operational phase.

Furthermore, the development of coatings gave another help for controlling the external corrosion. In the '70s the introduction of TMPC "Thermo Mechanical Process" was the latest breakthrough for increasing the pipeline steel strength, toughness without any detrimental effect on weldability



The basic concept of thermomechanical treatment (TMT) or thermomechanical controlled processing (TMCP) is responsible for the development of many advanced steel grades with improved mechanical properties during the last 50 years.

The basis to produce fine, homogeneous microstructures with improved properties. Starting from structural steels, improvements can be achieved with respect to higher strength and toughness values combined with better weldability and formability, **mainly based on reduction of carbon content and finer grain sizes**.

Overall scheme on pipe steel and production technique evolution in the last 60 years

ACCIAI PER OLEODOTTI

Negli ultimi 80 anni gli oleodotti si sono evoluti verso distanze sempre più lunghe, diametri sempre maggiori e pressioni sempre più elevate (attualmente 1450 lb/in^2).

Ovviamente gli acciai richiesti devono possedere:

- **elevata σ_y e σ_t**
- **sempre di piu' si richiedono alte pressioni 10-12 atm**
- **elevata saldabilità**
- **elevata tenacità**

Oltre a queste "ovvie" richieste si cerca:

- **resistenza al buckling (carico di punta) a profondità dell'ordine di 170÷200 m**
- **resistenza alle basse temperature (soprattutto quando si trasporta gas liquido)**
- **resistenza all' hydrogen-induced cracking (HIC) per petroli ricchi in H_2-H_2S etc.**

- Many new major Oil and Gas reserves are in remote locations and will require the construction of long distance pipelines.
- Pipeline construction costs can exceed:
  - $1M - $1.5M per mile for cross country pipelines
  - $3M - $5M per mile for offshore pipelines
- In many cases the cost of pipeline construction dominates the economics of Oil and Gas recovery.
- In addition to the capital investment associated with new pipeline construction, there is a need to extend pipeline design methods to cover increasingly demanding operating requirements.

Pipeline Cost Reduction

- High Strength Pipe Materials
- High Productivity Welding
- Advanced NDE Methods

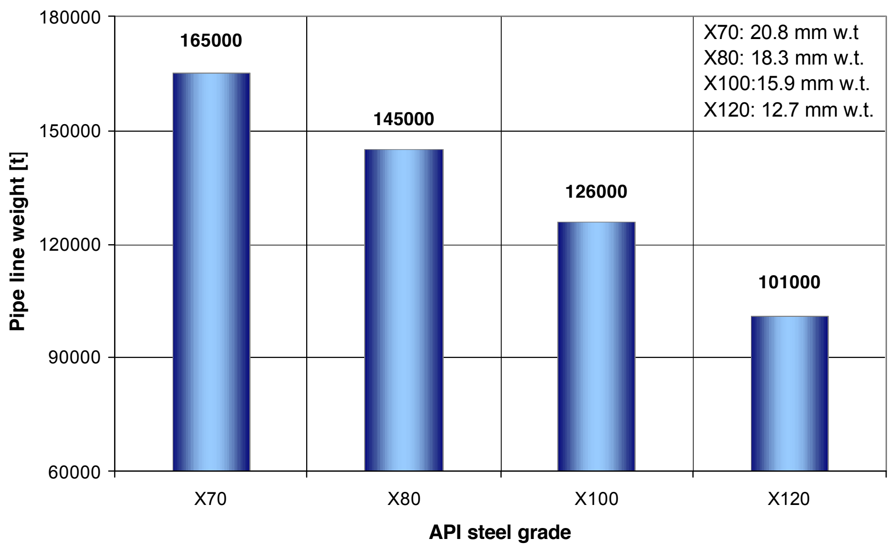


Figure 1: Material savings due to the use of high strength steel for a given pipe diameter

For short length pipelines the pressure drop due to frictional losses is small, so that compression is not required.

For longer pipelines, once the pressure drops then a re-compression stage is used to increase the pressure up to the level needed for the actual transportation demand. This process is regularly repeated along the pipeline.

The key fact in developing long-distance pipeline is based on the nature & volume of the fluid, the pipe length, location and terrain and on the possibility to cut the cost to reduce pressure drops by increasing the operational pressure.

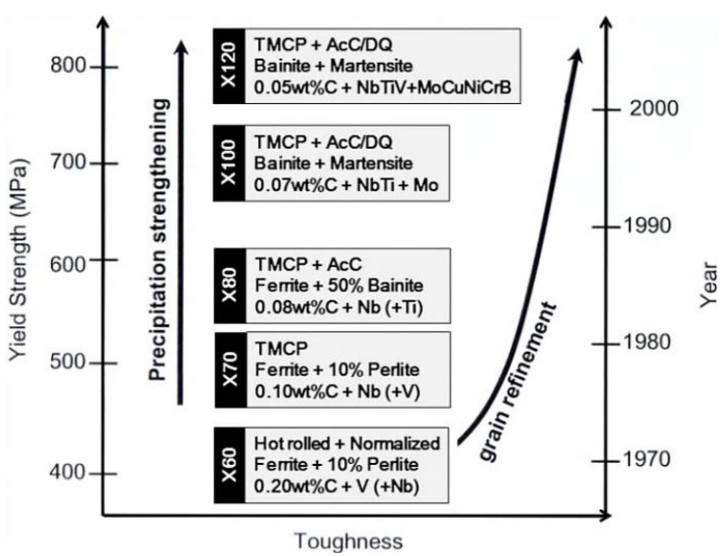
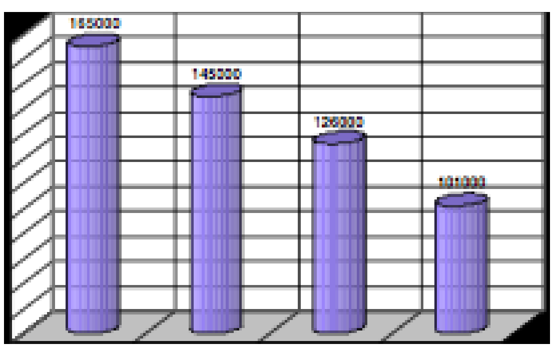


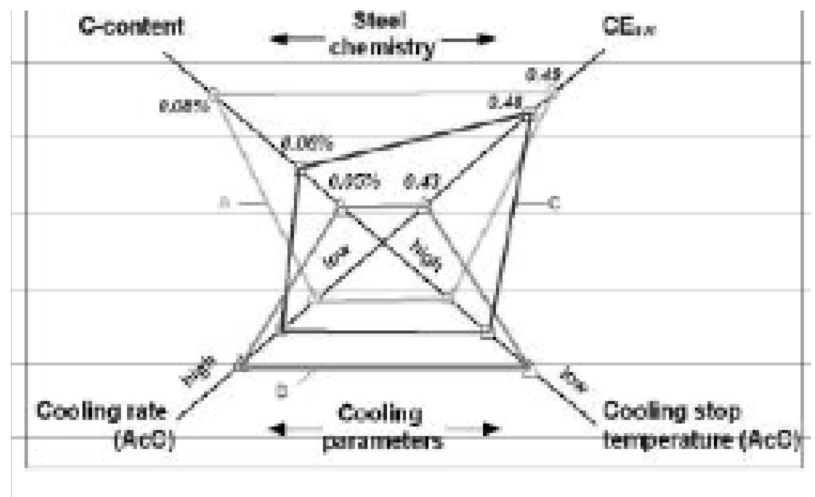
Figure 1. Evolution of line pipe steel grades as an example of HSLA steel development [4].

Molti degli acciai scelti si basano sulle tabelle dell'API (American Petroleum Institute); la prima risale al 1948 ed elencava un solo acciaio (X42 con $\sigma_y = 42$ ksi); attualmente vengono classificati acciai fino al X80 → $\sigma_y = 80$ ksi (80 ksi=551 N/mm^2) e anche X100 ($\sigma_y = 739$ N/mm^2 con una T di Transizione D-F di -15C)

La classificazione in "limite di snervamento" è dovuta al fatto che: maggiore è la σ_y, minore è lo spessore a parità di coefficiente di sicurezza.

(il passare da X70 → X80 porta ad un risparmio del 12.5% nello spessore, passare da X70 a X100 porta ad un risparmio del 30% nei costi).



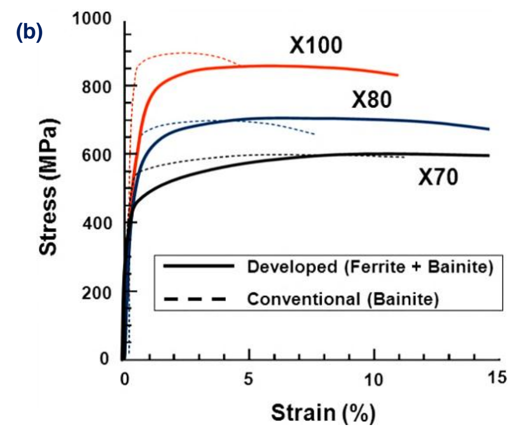


Current Status

- X80 Pipeline Technology
  - Proven methods for X80 pipe production
  - Good material properties (including crack arrest)
  - Proven construction methods
  - Cross country X80 pipelines constructed in Europe and Canada
  - Offshore X80 pipelines are becoming increasingly common (pipeline, flowlines, and risers)
- ***Summary***
  - X80 Pipeline Technology is Mature
  - The largest development “in field” application” is in North America and in the United Kingdom where most of the operating X80 lines are located

Table 1 Targets of X120 development

Property	Base pipe	Seam weld & HAZ
Tensile strength (TS) (circumferential)	YS ≥ 827MPa (120ksi) TS ≥ 931MPa (135ksi)	TS ≥ 931MPa (135ksi)
CVN energy@–30°C	≥ 231J	≥ 84J
CTOD@–20°C	≥ 0.14mm	≥ 0.08mm
DBTT of CVN	≤ –50°C	
B-DWTT SA@–20°C	≥ 75%	



Current Status

- *X100 Pipeline Technology*
  - X100 Pipeline Technology is at an advanced stage of development and demonstration.
  - Crack arrest performance is still not fully proven, particularly for high pressure applications.
  - TCPL constructed an X100 pipeline loop in the Fall of 2002 to gain experience with field construction.
- *X120 and Beyond*
  - Major proprietary R&D program to develop and assess X120 and X120+ pipeline technology.
  - Initial results are very encouraging.
  - gas transportation at a much higher pressure (25 MPa)

Ultra-high strength pipeline "X120," adopted in Canada

X60 si ottiene con processo termomeccanico controllato (controlled-rolled); ha una struttura ferritico-perlitica ottenuta con l’addizione di 0.03% Nb.

X65 e X70 richiedono oltre all’affinazione del grano apportata dal Nb un indurimento per precipitazione ottenuto con aggiunte di vanadio (0.07%).

X80 si migliorano e si controllano molto bene tutti i passaggi precedenti più si aggiunge Ni e Mo (0.35%; 0.29%).

The target tensile properties (Yield) of X100 and X120 were selected to be 690 MPa and 827 MPa (120 ksi)
fine **low carbon martensite** and **lower bainite** dominant microstructure is essential to achieve adequate fracture toughness at the strength level over 900 MPa. In order to maximize austenite hardenability while keeping C_{eq} low for enhanced weldability, **low carbon Mo-Nb and B free steel and low carbon Mo-Nb steel with a minute amount of B were designed for X100 and X120, respectively.**

The steel for X100 is
0.07%C - 1.83%Mn - (Cu-Ni-Cr-Mo-Nb-Ti)

steel for X120 is
0.05%C - 1.56%Mn - (Cu-Ni-Cr-Mo-Nb-V-Ti-B)

The C_{eq} are 0.21 % for X100 and 0.20 % for X120

Plates up to 20 mm thickness with at least 231 J Charpy energy at – 30C

X10 and 120 require Submerged arc welding (SAW)

the arc is formed between a continuously-fed wire electrode and the workpiece, and the weld is formed by the arc melting the workpiece and the wire. However, in SAW a shielding gas is not required since there is a shielding flux applied around the weld

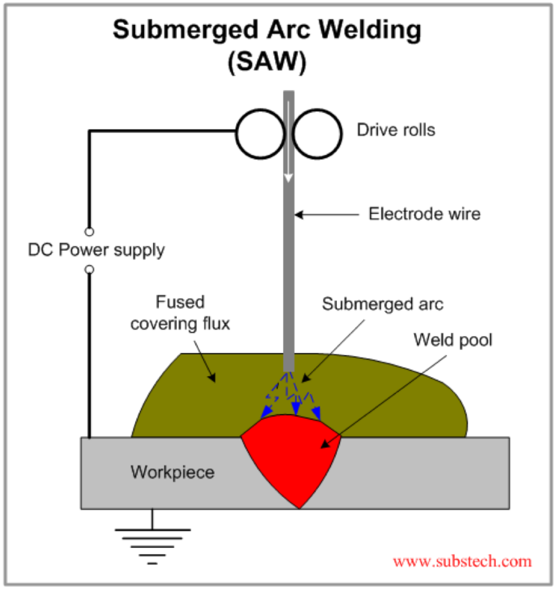
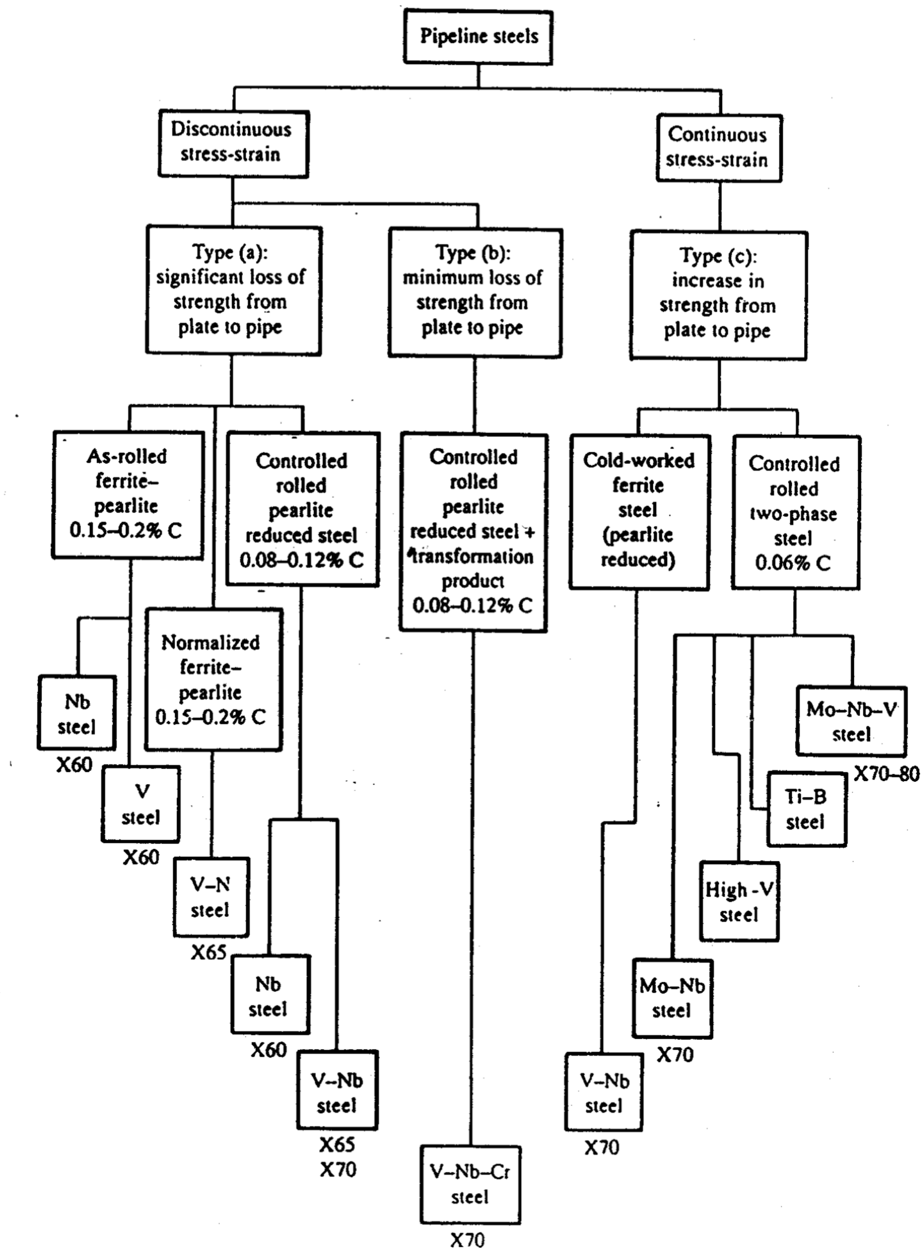


Table 4: Chemical composition of different weld metals

Wire / Flux-combination	Pass	C	Si	Mn	Cr	Ni	Mo	P_{CM}
C	Inside	0.06	0.30	1.93	0.98	1.57	0.83	0.33
	Outside	0.06	0.32	1.94	1.00	1.60	0.83	0.33
B	Inside	0.07	0.47	1.98	0.35	1.04	0.40	0.27
	Outside	0.07	0.50	2.01	0.35	1.12	0.41	0.28
A	Inside	0.05	0.26	1.95	0.21	0.22	0.52	0.25
	Outside	0.05	0.26	1.99	0.20	0.21	0.56	0.22



Pipeline steels
Discontinuous stress-strain
Continuous stress-strain
Type (a): significant loss of strength from plate to pipe
Type (b): minimum loss of strength from plate to pipe
Type (c): increase in strength from plate to pipe
As-rolled ferrite–pearlite 0.15–0.2% C
Controlled rolled pearlite reduced steel 0.08–0.12% C
Controlled rolled pearlite reduced steel + transformation product 0.08–0.12% C
Cold-worked ferrite steel (pearlite reduced)
Controlled rolled two-phase steel 0.06% C
Normalized ferrite–pearlite 0.15–0.2% C
Nb steel
X60
V steel
X60
V–N steel
X65
Nb steel
X60
V–Nb steel
X65
X70
V–Nb–Cr steel
X70
V–Nb steel
X70
Mo–Nb steel
X70
High -V steel
Ti–B steel
Mo–Nb–V steel
X70–80

Negli ultimi anni sta aumentando la richiesta di acciai per condutture per il trasporto di oli o gas “acidi” (sour) in pratica contenenti livelli significativi di **H_2S e CO_2** (la National Association of Corrosion Engineers -NACE-) definisce “sour” un fluido che contiene almeno $p_{H2} > 0.0035$ atm.

Entrambi i due gas diventano corrosivi in presenza di umidità e sono responsabili della corrosione del gas naturale altrimenti non corrosivo.

Normalmente i gasdotti non lavorano in condizioni corrosive ma una qualsiasi causa che faccia scendere la temperatura al di sotto di quella di “rugiada” del gas può introdurre umidità nella tubazione.

L’ H_2S produce due tipi di frattura:

- hydrogen-induced cracking (HIC)
- sulphide stress corrosion cracking (SSCC)

Il test per provare la sensibilità dell’acciaio all’H_2S si fa immergendo il provino in una soluzione marina saturata di H_2S a pH 5.1÷5.3 (test BP), altrimenti si usa una soluzione più aggressiva 0.5% CH_3COOH + 5% NaCl + H_2S (pH=3.5÷3.8) (test NACE). In entrambi i casi l’immersione dura 96h